Cobot

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Cobot stands for collaborative robot. Edward Colgate, Witaya Wannasuphoprasit and Michael Peshkin first proposed this term in 1996: they defined a cobot as "*a robotic device, which manipulates objects in collaboration with a human operator*" [Colgate et al., 1996]. Cobots were first designed in order to constrain human operator movements, in particular man-machine environments, but maintaining the human-object mechanical interaction: human movements are constrained by the definition of what is called virtual surfaces.

The simpler example of cobot principle is the "unicycle PCM" [Colgate, 1996]. In a common unicycle, the wheel can freely rotate, but its steering orientation is controlled by the human. In the unicycle PCM, the steering orientation is controlled by a control law depending on the position of the device on the ground; the rotation of the wheel is still free. This means that one degree-of-freedom is still controlled by the human (the motion of the device), but the device controls the other degree-of-freedom (movement direction). One compelling application of cobot use is shown in [Peshkin et al., 2001], where in a car factory the cobot is used as a chariot to transport doors of built cars. The cobot helps the operator carrying the door like a usual chariot would do, and displacements are controlled by the operator as it would be possible with a common chariot. The role of the cobot is to define virtual surfaces where penetration of the manipulated door is forbidden, or to provide safe escape paths from dangerous positions of the manipulated door. This is done by modifying the chariot trajectories in function of its position, thus preventing contacts between the manipulated door and the car, avoiding hazardous movements that would damage the car's painting.

Haptic devices are considered by part of the haptic researchers originated from the field of robotics as "*robots essentially designed for direct, physical interaction with human operators*" [Colgate, 1996]. Haptic devices can be considered as a mean to create a mechanical relation between a human and an artificial object, which does not really exist in the human's physical world, but exists only under the form of an algorithm into the memory of the computer.

Conversely, cobots have been designed to help humans manipulating real objects (see definition above), and we have seen that the mechanical interaction that exists between the human and the object in the natural manipulation situation still exists in the case of cobots. The role of the cobot is to modify the available degrees of freedom, for example by introducing movement constraints. In other words, a cobot modifies an already existing human-object mechanical interaction whereas a haptic device artificially creates a new one.

Cobots are thus defined as a mechanical interface designed to interact with a human without masking the mechanical interaction between the human (manipulating-person) and the manipulated object. The philosophy of such systems remains indeed in a shared control of motion between the user and the cobot, and in the fact that a cobot mechanically interacts both with the human and the manipulated object. To perform that, cobots interact with people only by producing software-defined virtual surfaces, which constrain and guide the motion of the shared payload, but no mechanical energy to the human-object interaction. In cobots, the source of mechanical energy remains the user, and a cobot is only able to modify the energetic link between the user and the manipulated object: from that point of view, the cobot is a passive device because it does not

bring supplementary energy to the human or to the manipulated object. In other words, if the user does not move the manipulated object, the cobot is not able to generate motion on its own.

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